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MAINTENANCE SERVICES IN DEVELOPING COUNTRIES **

Prepared by

P. De Groote ***

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*** Managing Director of DGS INTERNATIONAL, Belgium.

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1. INTRODUCTION

1.1 General information

The present paper is the report 2 of the First Expert Group Meeting Programme on computerized maintenance systems in metallurgy, organized by the United Nations Industrial Development Organization (UNIDO) in co-operation with the Institute for Automatization and Industrial Management (INORGA-Prague) under the auspices of the Czechoslovakian Ministry of Metallurgy and Heavy Engineering and to be held in Czechoslovakia from 28th January until 1st February 1985.

This report contains following basic topics, according to the terms of reference defined by UNIDO:

a) Overview of the principles of maintenance field services in iron and steel industries
b) Various types of systems used for planning, installation and documentation and coding of equipment and spare-parts
c) Rehabilitation of the production facilities and replacement of parts/assemblies and subassemblies
d) Preventive maintenance operation including lubrication, testing and inspection
e) Case studies of specific examples of above in various developing countries

The report has been prepared by Mr. P. DE GROOTE, Managing Director of the plant engineering company DGS INTERNATIONAL N.V.-Belgium, specialized in Industrial Maintenance in Developing Countries.

1.2 Industrial maintenance problems in developing countries

"Transfer of technology from developed to developing countries" and "adequate technology for developing countries" are fashionable words. They emerged some 15 years ago, and yet it is not always clear exactly what they cover. In particular, industry and the political world have different views of the problem. The aim of this paper is to present the point of view of those who have to operate and maintain plant or equipment in factories.

One can say that transfer of technology starts at the planning stage of a plant and ends - if it is successful - with the working and the maintenance of this plant, run by local workers, facing local problems, and under local conditions.
The whole process which lies between planning one plant and the operation (or break-down) of the plant can be regarded as transfer of technology.
This transfer is a very complicated matter, which depends largely upon the nature and the size of the plant, upon the skills and abilities of the partners, upon the local circumstances, and many other elements.

Experience shows that the process of technology transfer has not been very efficient in the past years, and that in particular the maintenance function has suffered from this deficiency. It is important to examine why this is the case.

As everybody knows, the process of independance in the third world has initiated a new era, in which industrialization is an important element. Industrialization under colonization was limited mainly to the exploitation of local natural resources,

with little effort to achieve real transfer of technology. The exploration and development of oil and gas, and above all the different oil booms since 1973, have resulted in enormous industrial investments in some of the under-developed countries. This industrial boom is unique in history and we should not forget that the building up of industrial infrastructure in the traditionally industrialized countries took more than 200 years. At the beginning of this boom, both the countries concerned, as well as the exporters of industrial plants in our countries, were in the seventh heaven of delight.

Young countries dreamed of their plants, which would produce high-quality products of different kinds, and they were prepared to put the necessary money on the table. And precisely here arose the first bitter experiences. Indeed, the hard realities are not as attractive as the dreams. Very many industrial plants stand still or operate very poorly, cannibalized equipment is virtually the name, and most of the time the products do not meet the quality standards, for which the machinery was designed. The consumption of spare-parts is dramatically high, the motivation of the personnel dramatically low. Certainly, one should not overgeneralize this situation - it is evident that some plants work better than others, and that not all countries have the same problems - but the trend, the pattern is the same everywhere. From the more than 150 maintenance audits which we have carried out in various industrializing countries, it has appeared that the average technical availability of the industrial equipment in those countries amounted to not more than 32 %. The remaining 68 % of the time the equipment was not available, and this was due to technical reasons and not to such economic causes as the lack of raw materials or to problems related to selling the products. Moreover we found out that 80 % of this unavailability was due to problems of industrial

maintenance. Another trend which should be mentioned incidentally, is that the older plants generally work better than the newer ones. Our experiences show that these trends can be generalized to most of the developing countries.

Under these circumstances aught we to be surprised at experiencing a certain disappointment, both on behalf of the purchasers of industrial plant, and of the constructors and exporters ? The newly industrialized countries have experience of plants producing only fractions of the yearly capacities they were designed for, and even then generally of bad quality. They have to spend enormous amounts to keep them more or less going. All those who thought may had paid enough for good engineering and good construction had to audit that their cement plants did not produce cement and that their steelworks made hardly any steel. Everywhere one has then sought for a reason to blame the supplier or contractor for the poor performance, and the reasons were generally easily found. The purchaser of the plant started then to get tougher in his requirements, and demanded a plant to produce a high quality product even under local circumstances and even after some years of operation. This gave existence to the so called turn-key plants, and to other contractual forms by which the client tried to implicate the constructor in the production results by financial participation or other means.

The supplier of the industrial plant in his turn, shakes his head at seeing all the efforts the purchaser makes, and the claims he puts forward. For him the matter is clear : the purchaser has neither the personnel nor the infrastructure nor the industrial tradition and ambition to set up a successful industrial productive enterprise. The average western contractor shakes his head when hearing the claims of the purchasers, and

considers the training of personnel, the supply of an adequate technical documentation and the supply of a correct organization as additional jobs, which he has to assume if he wishes to win the contract.
In all this discussion, one forgets one major thing, namely that the future plant must be ran, operated and maintained. One forgets that it is a different job to operate and maintain a plant in Nigeria or in Bangladesh rather than in Germany or in France. Here lies the key of the problem.

When reviewing the different parameters which affect the operation and maintenance of industrial plant in a developing country, one must make the distinction between 4 major groups of problems :

- personnel problems
- problems related to the technical equipment proper,
- spare parts problems, in the the broadest sense,
- problems related to the local infrastructure and logistics.

Let us look at these parameters more closely in order to examine the content of an "adequate" transfer of technology.

First major problem : personnel
Anyone who has ever visited an industrial plant of any importance in a developing country knows the extent of the personnel problems. Apart from the problems of motivation and attitude towards the job, the technical qualification of the personnel is generally extremely low, mainly at the level of the craftsmen and the foremen. The complete lack of technical schooling, but above all the absence of the industrial tradition and experience, mean that the daily practice of maintenance is,

in a word, a catastrophe.

The magical word of training appears therefore in block letters in each and every contract of construction. But in most of the cases, this training is reduced to a vacation stay in Europe or to a completely inadequate training. The training is only given to the top-level personnel of the future plant, and not to the key-people of the production. If training is given to production-people, generally it is limited to the operation personnel, and the poor foreman who has to be able to maintain and repair the machines later is neglected.

The few technically educated people are generally badly employed. The organization is most of the time inadequate and not followed. In addition, the mentality of the personnel towards the requirements of the modern industrial society is a very difficult and delicate problem indeed. People who have demonstrated remarkable self-discipline in an agricultural or artisanal environment, do not succeed in acquiring a collective discipline, which is essential for every industrial pattern of society.
Problems of motivation exist, which originate from the same problem of lack of industrial tradition and also from the fact that many of the workers do not understand the importance of their proper job. How can you expect discipline from lubricators - a very important function - if the lubricator does not understand the usefulness of lubrication.
Personnel problems are sometimes solved by the so-called technical assistance. But apart from the fact that it is very difficult and thus very expensive to expatriate good experts, one must face the fact that technical assistance cannot be a solution and must be considered as a palliative.

Second group of problems : the equipment.
Generally problems with the equipment arise at a very early stage and are caused by a poor investment policy. The plant location is often bad (the plant is built too close to the sea, or in areas unsuitable from a technical point of view - lack of energy or water, corrosion problems, etc.-). The equipment is often too sophisticated with a lot of electronics and instrumentation, or in some cases also hopelessly old. Generally speaking, no attention whatsoever is paid as to the future maintainability of the plant (accessibility - repairability, etc.). In addition, the lack of national standards and the variety of suppliers, constructors and sub-contractors, create a basic problem of spare parts, which never can or will be solved. There is also the aspect of honesty: there are indeed cases where engineering companies design a plant which will never be able to produce, for purely technical reasons. There is the improper operation of installations where examples battle the imagination. Maintenance managers in developing countries will surely be able to confirm examples of machines, which were designed for a life span of 20 years and which had to be replaced after 3 or 6 months of operation. The lack of industrial experience means that the machines are badly operated and hardly ever maintained, so that the life time is very short. Generally there are no policies for replacement, which has as a consequence the existence of enormous bottlenecks, even within one plant.

Let us now look at the third group of problems : spare parts. Shortage of spare parts is a permanent nightmare for all those who operate and maintain an industrial plant in a developing country. First of all, there is the element of vulneraliblity of

the installations in such a country. A difficult climate and natural environment, human shortcomings, lack of local technical support, and very often badly chosen material make that the consumption of spare parts is relatively much higher than in the industrialized countries. In addition to this, one must say that the purchasing of spare parts creates enormous problems : the identification and codification of the parts is an almost impossible job due to language problems, and the technical documentation is most of the time incomplete, not clear and inadequate. In fact, experience has proven that the lack of adequate technical documentation is one of the most serious handicaps which developing countries encounter when trying to "acquire" a technology. Enormous problems exist in finding a supplier for one or another spare part : these problems start with the difficulties in finding the name of the supplier and end with the difficulties in persuading the supplier to sell the parts in question. In fact, very often parts which cost a few cents may determine the break-down of whole plants and a supplier may very well not be interested in selling such a small part. Moreover, there exists the problem of international banking transfer, the difficulties of customs clearance and the sometimes unbelievable burocracy which slows down the commercial transaction, up to a point where there is no movement anymore. When they finally arrive, the parts may be stocked in bad conditions, and arrive in stores which have a very poor organizational structure, so that the parts may sometimes be lost for ever.

As to the last group of problems - infrastructure and what we call logistic support - one can be brief. Housing problems, supply problems, power cuts, no telephone lines, bureaucracy, inefficiency, slowness, corruption : all elements which make the operation and maintenance of technical equipment in the third world so difficult and frustrating

2. PRINCIPLES OF MAINTENANCE FIELD SERVICES IN IRON AND STEEL INDUSTRIES

2.1 The maintenance function

The aim of the maintenance function is to assure the maximum availability of production equipment and utilities at an optimal cost.

From this point of view the role of maintenance is substantially more important than that of a simple emergency or repair section: the maintenance function is a productive function and it is necessary to pay the same attention to it as to the operating function. Maintenance contributes not only towards assuring a continuity in production, a constant quality and a minimal cost of final product, but deals equally with the conservation of the equipment.

In order to reach these objectives, maintenance will be put into practice in various forms :

- breakdown maintenance

  This approach is also referred to as "repair" maintenance but is not in the true sense a system at all. No service is carried out, unless a failure has occured. Sometimes, no maintenance men are on call, and in metal-working shops, machine operators often repair the machines that they themselves use. No effort is made to find out the reasons for the breakdowns.

  At first sight it looks very economical and perhaps for a short period it may well prove so, but management is getting no information on how much it costs to keep the plant

running, there is no summary of time lost due to breakdowns and only occasionally does a shop foreman complain that he can do no more. When a repair bill has to be paid management shrugs it off and instructs the book-keeper/accountant to charge it to "miscellaneous" expenses.

- preventive maintenance consists in examining and working on the equipment at predetermined intervals in order to detect and prevent damage to the machine or premature wear before break-down. Preventive maintenance has an anticipating character. The most important preventive maintenance works are : planned interventions, lubrication, systematic visits and cleaning, overhauls, inspection.

- condition-based maintenance consists in monitoring the equipment during operation (analysis of vibrations, sounds thermovision and thermography, ultra-sonics, frequency spectrum etc.)

- plant improvement maintenance to improve systematically the equipment in order to :
  - increase maintainability;
  - ease operation;
  - improve quality and quantity of final product;
  - assure safety of personnel.

Maintenance covers various tasks :

- Planning. The planning section is responsible for maintenance methods.This section has in fact a preparation task, which does not concern a specific job (this is carried out by the work specification or preparation desk), but

consists in the organization of all elements in respect to technical information, work instructions, spare parts, etc.

- Engineering and construction. Maintenance deals with engineering studies and construction for modification or for small extension of the existing equipment in order to improve capacity and efficiency, quality of final product, maintainability, operation or safety.

- Work specifications (or job preparation) and estimating Work specifications determine the details of the activities, the different phases of the operation, necessary supports, job timing, manpower and material estimates. This task results immediately from the planning task and concerns a specific job.

- Maintenance programming is responsible for programming of all maintenance work and is highly linked with the work specifications task.

- Maintenance scheduling assures the planning of workload allocated to the different craftsmen

- Job execution is done by the intervention teams on site or in the workshop

- Spare parts manufacturing consists in producing spare parts in the central workshops.

- Work-performance control function is assured by supervisors and foremen. Requires detailed instructions on how to proceed and which tools or instruments are to be used.

- Spare parts management and stores assure the availability of spare parts and maintenance material at the right time and on the right place in an economic way.

- Maintenance management defines an overall-policy based on an analysis of maintenance costs and all data about machine operation and maintenance.
  This task is highly linked to the planning section and accounting department.

2.2 Organization of the maintenance department in a steelplant

2.2.1 Maintenance organization chart

The organization-chart which is shown in Annex 1 is meant as a guide, which may be useful when discussing the various problems and activities of the maintenance department. The chart shows the principles of an organizational structure for a maintenance department and cannot be considered as an all purpose organization-chart, which may find application in any plant.

The standard organization-chart is composed of 7 centralised divisions, each under the responsability of a superintendent : central maintenance support office, mechanical division, electrical division, instrumentation division, the central workshop, spare-parts management and stores, and general maintenance division.

All the superintendents report to the maintenance director (general superintendent). In the case of large steelplants, some

of the divisions may be decentralized by production zone (i.e. ore handling, blast furnace, steel casting plant, hot and cold rolling mill, etc.). The central workshops and the spare-parts management should in any case be centralized.

In certain cases it may be justified to separate the general maintenance division from the rest of the maintenance department. The central workshops may possibly be decentralized as far as their organizational structure is concerned, although they will physically be centralized. For instance in small plants it may be justified that the electrical workshop depends on the electrical division, whereas the mechanical workshop depends on the mechanical division.

In certain cases the instrumentation division may depend on the electrical division.

Many modifications of the standard organizational chart are possible and may be justified in some cases. The chart represents a general organization from which the principles may be applied in any plant.

2.2.2 The various divisions of a maintenance department

2.2.2.1 Central Maintenance support office

The standard organization-chart from the central maintenance support office is shown in Annexure 2.

The maintenance planning section is composed of a centralized office with other decentralized offices in the various production zones of the plant.

The condition and behaviour of the equipment should continuously be observed by the planners, each of them in his production zone.

The maintenance engineering and construction section has at its disposal a drawing office and will deal (apart from modifications and small extensions) with keeping drawings up-to-date and participating in the standardization of parts and machines in the plant, as well as with plant improvement studies.

The tribology section will deal mainly with the planning of greasing and oiling, with the organization and the inspection of lubrication work, and with the selection of oils and greases.

The maintenance management section takes charge of the analysis, the management and the control of the cost of maintenance.

The central documentation section will gather and manage all documents, drawings, plans, catalogues, etc. regarding the plant and its equipment.

In order to enable a correct flow of documents, a Copying Section , equipped with photostating and other copying equipment is necessary.

2.2.2.2 The mechanical and electrical divisions

Annexure 3 shows the standard organization-chart for mechanical and electrical divisions.

The mechanical and electrical divisions deal in the first place with trouble-shooting repair on the spot, supervision of the equipment and carrying out the routine and preventive maintenance work. They are responsible for the quality of the work and for the activities of the craftsmen. In order to facilitate internal communications and in order to specialize the personnel in one of more production zones, the electrical or mechanical divisions are decentralized by the creation of local sections in the different zones of the plant. Each zone of the electrical and mechanical divisions would be composed of two parts: maintenance programming - work specifications - maintenance scheduling (PSS) and the intervention team who are split into day crew and three crews as 8 hours shifts giving 24 hours cover.

Centralising of PSS at the level of the central maintenance support office can be justified in small or medium-sized plants. The function of "inspection" of the installations, which is frequently carried out by the maintenance planners, can equally be integrated into the work of the foremen. This function consists in detecting the causes of possible break-downs before actual break-downs occur. This is carried out by a programme of systematic visits. Experience shows that 70% of break-downs could be avoided if the visits were well organized.

2.2.2.3 The instrumentation division

Annexure 4 shows the standard organization-chart for the instrumentation division.

The instrumentation division deals with the apparatus and equipment for control and regulation of the plant, as well as

with all pneumatically and electronically controled equipment.

The principles of decentralization and organization, as described for the electrical and mechanical division are equally applicable in this case.

Frequently the telecom-service, which deals with all telecommunication equipment of the plant, is linked to the instrumentation service.

2.2.2.4 The central maintenance workshops

Annexure 5 shows the standard organization-chart for the central maintenance workshops. This chart applies to a universal and complete maintenance workshop.

Machine-tools are part of the metal-working section of the mechanical workshop. In some cases, there may be a large number of these machines.

All work concerned with metallic contruction and erection are part of the sheet metalworking, piping, welding and cutting section. A team of specialized welders (high pressure welders, welders of non-ferrous metals etc.) is not always justified but will depend on the frequency of this work and of the possibility of sub-contracting it.

The foundry and the forge are an essential element in the manufacturing of spare-parts. Often sub-contracting may replace such equipment, as it may also for other specialized shops such as gear cutting, toolmaking, heat treatment, chrome-plating, metallisation, diesel engines, pumps, vulcanizing, hydraulic

equipment, overhead traversing bridges, refractories and maintenance section for machine tools.

The repair shops deal with important overhauls, as well as with repairs in the shop and on the spot. On the spot repairs should be avoided as much as possible. It is better to take apart the machine or subassembly in question and repair it in the central workshops. If repairs on the spot cannot be avoided, the central workshops' crews will deal with them.

The electrical workshop contains a rewinding section. In some cases a factory lighting section may be justified.

A PSS section in each shop will deal with the planning and the preparation of the jobs.

Intermediate and final checks will allow the quality and the rate of output of the jobs carried out by the craftsmen to be controlled, whereas testing-lines (electrical, hydraulic, pneumatics, etc.) will confirm the reliability of the manufactured or repaired parts.

2.2.2.5 Spare-parts management and stores

Annexure 6 shows the standard organization-chart.

A "selection of spare-parts" and "codification of specific parts" section will deal in the first place with the selection of all the spare-parts, which should be kept in stock to assure a normal operation of the plant. This section will deal at the same time with the codification of the safety parts (subassemblies or parts which are subject to very little wear,

but which have a critical importance for the operation of the equipment) and of specific parts (parts for one well-specified machine or equipment, and thus of one well-specified manufacturer).

The "codification of standard parts" section will deal with the codification and the designation of standard parts and of all maintenance materials.

The "standardization" section deals with the standardization and interchangeability of parts with a high turn-over. This is the basis for an economic management of those parts, since it will limit the number of stock items, eliminating equivalent or identical parts.

The "spare-parts administration" section deals with the proper management of stock. The section has at its disposal a stock control card on which all the information for sound management is written down. This will enable the purchase of parts or material according to one of the existing models for spare-parts' administration.

Automatic stock-administration will require an EDP-section, whose role is to "translate" the parameters for manual management into computer language.

Common parts and articles are stocked in a central store, which may possibly have some decentralized stores in different zones of the plant. It is the central store which will receive the parts, which will distribute them and which will keep the parts and articles in stock.

2.2.2.6 General maintenance

Annexure 7 shows the standard organization-chart.

General maintenance normally has its own teams for operating and maintaining the factory utilities (facilities for production and distribution of energy and fluids such as electricity, air, water, gas, steam etc.).

The "maintenance of rolling equipment" section will have at its disposal its own maintenance infrastructure (garage, store, etc.).

The maintenance of the buildings is done by a special section, which has at its disposal electricians, plumbers, carpenters, painters, etc. This section will enable the maintenance workers of the production equipment to be discharged from secondary tasks.

The "materials handling" section will have at its disposal crane-drivers, drivers for light and heavy vehicles, drivers for lifting equipment, etc. The craftsmen for civil construction will consist of masons and will deal with the general maintenance of the civil engineering works. The craftsmen will also participate in plant extension works.

3. PLANNING, INSTALLATION, DOCUMENTATION AND CODING OF EQUIPMENT AND SPARE-PARTS

3.1 Planning of the factory

The role which future plant operating staff play during the process of purchasing and constructing new plant is of vital importance for the future of the plant. In fact, sound operation of the plant may depend on the contribution of the future operating staff at the early stages of design and engineering.

Every contracts manager should make a detailed study of the arrangements which should be made when buying the equipment. When making contract specifications and when carrying out the construction of the project one should call upon past experience at operational level. In particular, much attention should be given to the experiences and requirements of the maintenance department. It is therefore necessary for maintenance personnel to participate in the preparation of the project in setting up contract specifications, and in selecting the constructor or suppliers of the equipment.The following remarks apply to design, supply, erection and commissioning. Some of them can be translated into separate technical specifications, which may be integrated in the general technical contract specifications:

- from the moment that engineering starts, all attention should go to the adequate maintenability of equipment : accessibility, ease of assembly, repair, safety, standardization, frequency of interventions for preventive maintenance ...;
- the selection of equipment components should be done according to international standards. Technical specifications should also include company and plant standards;

- designation and marking (e.g. standard colours) from both drawings and equipment should be clear and simple;
- the purchaser should be able to inspect the machines before assembly:
  - at the manufacturer's : drawings, technical documentation, list of subcontractors; assembling in the plant before shipping, commissioning in the plant;
  - when packing and at shipping;
  - at arrival of equipment on site;
- for follow-up of erection, the purchaser should have the right to call on a third person (e.g. consulting engineer) in order to check whether the erection is in accordance with the technical specifications and according to professional requirements;
- the supplier should provide a detailed schedule of personnel to be engaged on site according to the progress of the project;
- training services should be clearly defined: practical training during erection and start-up, control of results;
- commissioning and start-up periods are essential : the requirements for equipment and personnel support should be clearly stated;
- clear and detailed description regarding conditions of intermediate acceptance (acceptance levels), performance tests, provisional acceptance, guarantee period and final acceptance;
- clear description of what is expected from the supplier as far as the organization of the various departments of the plant in general, and of the maintenance departments in particular are concerned;
- conditions regarding the completion of plant erection and termination of sitework;

- spare-parts should be studied in detail. It is important to provide separate specifications;
- the technical documentation also deserves separate specifications;
- technical assistance services before and after final acceptance should be clearly specified. The responsibilities and competence of the assistance should be clearly stated;
- conditions and details of after-sales-service;
- penalties in case of non-respect of contractual clauses should be clear and strict.

Another important point in planning factories in developing countries is the choice of adequate technology. An adequate technology does not always mean a simple technology. The adequacy rests more on the reliability of the equipment run under difficult conditions : distance of the country with regard to suppliers, difficulties in communication, climatic conditions, shortage of skilled workers, badly operated equipment.

The adequacy of machinery with respect to maintenance personnel refers especially to:
- accessibility;
- visibility and marking;
- possibility of disassembling;
- possibility of repair on site;
- avoiding over-sophisticated technology;
- safety measures;
- toleration of operating errors;
- robustness;
- clear and complete technical documentation.

3.2 Installation of equipment

The shortage of skilled workers is reinforced in most cases by the lack of social infrastructure of the region where the plant will be built.

The first phase of construction of a plant should consist of construction of dwelling houses for the personnel.

During the preparation of the site, a detailed geotechnical study should determine whether the selected site meets the requirements of the projected plant. Close attention should be given to adequate draining, fences, easy access, etc. A basic infrastructure should immediately be provided, even if provisional : supply of electricity, water, telecommunications (very important), administration, wide roads.

Erection of auxiliaries (workshops, stores, offices, utilities) before assembling of production equipment will not delay the progress of construction, on the contrary. It will be beneficial during the whole erection period. These general means should not be considered optional (loss of money and time).

The following is required :

- spacious and covered stores for spare parts and consumable materials with possibility of extension;
- customs zone;
- uncovered storing parks, well drained and with easy access and handling facilities;
- construction of central workshops with the possibility of extension. One should start with metal-construction, welding, piping shops followed by joinery, machine-tools, electrical

workshops, etc.

As far as civil engineering, steel construction work and the installation of roller bridges are concerned, the following items should be studied carefully : waste-water network (be careful of water containing acid), adequate draining (both of workshops and of railroads), evacuation of scrap, etc.

Erection of production equipment cannot start unless all the foregoing works are finished. Scheduling should be realistic. Too often one is faced with the problem of delays which results in quick and inaccurate completion of the final work. This becomes especially apparent during assembly and commissioning of electrical and instrumentation equipment.

The required lighting and plug sockets, properly fixed in height, conforming to safety standards should be provided, from the beginning of assembly of machinery. One must insist on clarity and cleanness during and after erection. All flimsy work should be avoided during erection : clearly mark lay-out of electrical cables, instal logical and correct piping, exclude provisional electrical supply by means of unsuspended cables, etc.

Commissioning of equipment according to the progress of erection, precedes the starting-up. These two phases are very instructive for maintenance personnel and the engineering company has to commit itself in enabling the future management to obtain maximum efficiency from it. Especially electricians and instrument technicians should participate in all commissioning of electrical and instrumentation equipment (control of sequences, simulation of faults, control of all

alarms, signals, protections and automatic devices, etc.)

During these phases, previously prepared safety instructions should be strictly applied. The personnel should be informed on the danger of serious accidents during start-up operations (electrical power, connection, getting up steam, etc.).

During the start-up, the necessary personnel, spare-parts, tools, raw materials and consumables for production should be permanently provided.

The tests after start-up will allow the necessary adjustments to be made and the check-up of all functioning circuits. They will also enable the control of adequate operation and synchronization of interdependent machinery. The workload of the maintenance department, especially of the workshops and the instrumentation and electrical division will be high during this phase.

The period after start-up of a plant is decisive for its future running. In that phase technical assistance will be very important, and will be required to solve together with the plant management a lot of unexpected problems. The organization which has been set-up should now be analysed in order to adapt it to the needs of the plant.

Technical assistance should be withdrawn only gradually after the training and installation of local personnel. Progressed redrawing of the assistance will enable the personnel to deepen their knowledge concerning the functioning of machines and to familiarize themselves with internal procedures.

3.3 Documentation

3.3.1 Introduction

Inadequate technical documentation is one of the major problems which industries in developing countries face.

When acquiring a factory, the importance of the technical documentation is generally underrated, both by the supplier and by the purchaser.

Most of the suppliers of factories for developing countries miss experience in operating the equipment in a non-industrial environment. The client on his side accepts what is being given to him and becomes aware too late that the technical documentation can not be adequately used.

The inadequacy of technical documentation is particularly harmfull to the maintenance department. Good maintenance is not possible without good documents.

3.3.2 The objectives of technical documentation

3.3.2.1 At the construction stage

- the follow-up and control of civil engineering works;
- checking the accordance of the machines with the specifications of contract;
- follow-up and control of erection;
- follow-up and control of tests and commissioning;
- enabling machinery to be correctly operated;
- enabling full control of the production process;

- achieve an efficient transfer of technology;
- adequate training of production personnel.

3.3.2.2 At the operating stage

- enabling the preparation of the preventive maintenance programme based on the maintenance cards;
- preparing the lubrication programme based on the lubrication cards;
- efficient preparation of the maintenance interventions based on the machine file and the preparation cards;
- set-up machine files;
- set-up maintenance planning;
- reduction of time spent on maintenance activities in particular on trouble shooting;
- facilitate assembling and disassembling;
- improve safety;
- adequate training of maintenance personel;
- enabling a sound selection of spare parts and consumables to be held on stock or to be manufactured locally;
- allowing an adequate standardization of the spare parts.

Poor or inadequate technical documentation is one of the main origins of bad maintenance and affects directly the factory's productivity. It therefore deserves great attention, especially at the stage of contract negociation.

Sound technical documentation is expensive and amounts on average to 10 % of the cost of the equipment. This important investment is justified only when technical documentation is used efficiently. Documents should be updated regularly and be available upon request.

3.3.3 Contents of technical documentation

Complete technical documentation covers three fields :
- the documents regarding engineering and design;
- the documents regarding erection and commissioning;
- the documents regarding plant operation, including maintenance.

The third category, which is considered hereafter more in detail, is the most important for the proper running of the factory. A part of the documents used for erection will be integrated into the technical documentation regarding plant operation and maintenance, since some of these documents may be interesting to the maintenance personnel.

The documents regaring operation and maintenance contain :
- mechanical drawings and general documents;
- drawings, circuits and other documents regarding electrical and automatic control equipment;
- drawings and documents regarding fluid circuits;
- spare-parts;
- service manuals for principal machines;
- operating manuals.

The service manuals should contain :
- general specifications;
- instructions for assembling and disassembling;
- instructions for adjusting brakes, clutches, transport belts, etc.
- complete instructions for starting-up, adapted to the level of local personnel;

- lubricating instructions, lubricating cards, lubricating planning, selection of lubricants, lubricating drawings;
- information regarding preventive maintenance;
- for standard equipment, such as diesel engines, compressors, etc. the workshop manuals for periodic overhaul and the complete parts lists;
- list of possible break downs with their symptoms, consequences and recommended action;
- for electrical and automatic control equipment, repair and trouble shooting instructions, testing circuits, information regarding electric motors, transformers, etc.;
- check lists and test programs;
- lists of special tools;
- lists of measuring instruments and control devices.

3.3.4 Delivery of technical documentation

Generally the technical documentation arrives when the factory has already started up. The maintenance department has to start work without any technical support, and it frequently happens that damage is made to vital parts of equipment due to lack of documentation. Documentation should be delivered with a sufficient number of copies and should be reproduceable in order to be kept up to date.

Following advice should be given to the suppliers :

- the technical documentation should be adequately packed;
- the documents which may affect the construction of the factory on site should be sent soon after signing the contract;
- all modifications should immediately be notified to the client;

- all documents regarding the equipment should be delivered before the arrival of the machines on site;
- the complete technical documentation should be delivered before provisional acceptance.

Severe penalties should be applied in case of non-respect of contract clauses regarding technical documentation (either for late delivery or for inadequate documentation).

3.4 Coding of equipment and spare-parts

3.4.1 Coding of equipment

Many years of industrial experience have taught us that an efficient maintenance is not possible unless the production equipment is listed and codified. This identification is used both for drawings and specific spare-parts classification as for maintenance purposes.

In this way it will be possible to specify the location of break-down or repair both to the maintenance teams as well as to the spare parts store-keeper. This will enable evaluation and testing of same standard subassemblies at different locations.

The codification system should be set up from the very start of the project. The industrial architect or engineering company should propose to the client the list and the exact location of the machines to be installed, in order that a proposal for codification can be made in good time.

In order to achieve uniformity of plans and drawings, it is essential to mention on each of these the drawing number of the

supplier or manufacturer and the factories own code number.

Codification is carried out in three stages, (e.g. the code number is composed of three groups of numbers). The first numbers (two or three numbers depending on the size of the factory) form the first group and fix a section or zone within the factory. This group of two or three numbers is also used to indicate the cost centre of the machine.

The second group of two numbers, together with the two or three first numbers indicates the specific machine.

The third group also composed of two numbers, indicates the sub-assembly concerned.

3.4.2 Coding of spare-parts

Spare parts cause great concern to any manager of technical equipment in a non-industrial environment. At least 50% of the unavailability of equipments is due to a lack of parts. Close attention should be given to this problem from the moment that engineering of new equipment is undertaken.

The consumption of materials and spare-parts is influenced by several factors:

- the number of wearing parts ;
- the load on equipment and its elements, according to the type of the production process and the degree of utilization of the production equipment;
- the lifetime of production equipment;
- the technical level of production and maintenance personnel;
- the motivation of personnel;

- management and care of production equipment;
- the general organization of the plant and of maintenance in particular.

The level of stocks and the size of a maintenance store (both for a plant and for a region) depend, apart from the factors mentioned above, on the following elements:
- industrial infrastructure of the country or region;
- the availability and respect of national and plant standards;
- the delay in reordering of spare-parts;
- commercial and administrative strains on the purchasing of spare-parts;
- the plants to be served, as fas as number, type and geographical location are concerned;
- transport facilities between the spare-parts stores and the plants;
- delays in availability of the spare-parts.

During the different enquiries which we have carried out in metallurgical plants of developing countries, we have noted that the selection and the quantity of materials and parts to be stored are not in accordance with the needs of local operating conditions. The quantity of specific parts is insufficient and standard parts and consumables are generally not provided.

Annexure 8 shows some empirical values concerning the need for spare-parts and the annual consumption in developing countries. These figures are only given by way of example and should be adapted according to the industrial sector.

It is essential to set-up a codification system of spare-parts, consumables and current store-items. Without a uniform and

common language, it is impossible to centralize the spare-parts management and stores for different production zones or units.

The way in which codification is carried out will determine :
- the quality of stock management and stock administration;
- the quality of storage and consequently the distribution to users;
- the accuracy in the expression of user's needs by means of a purchase request or issuing sheet;
- correct reordering by the purchase department;
- proper delivery by the supplier.

Good codification is even more important when stock administration and purchasing are treated by EDP.

A code number and a designation have to fulfil to the following requirements:
- a code number must correspond with one item and only one
- an item must correspond with one code number and only one
- a code number must be definite. A change of a code number already known to the users, already applied in the stores and already registered in administration and purchasing, is a constant source of error and should be avoided;
- the code number must be logical, i.e. it is given according to a codification grid which takes into account the main characteristics of the item which has to be codified;
- the designation must be studied very carefully :
  - it has to be complete and should exclude ambiguity;
  - it has to be clear and understandable to each user;
  - it has to be known all over the plant
  - it should adapt to the restrictions imposed by EDP and the system of purchase activities (i.e. the designation

must be clear to an "outsider").

- the designation of a specific item has to be the only one existing in the plant. In the case of a company with different production units, it is important to introduce one single codification system which can be applied to all the plants of the group.

In the steel industry different codification systems exist. Most of all the system based on codification according to the nature of spare-parts is used. It is a morphological codification. One starts with a broad classification of products which is in fact a sorting process, devided in 10 classes (from 0 to 9). The classes are then each subdivided in families, sub-families, groups and sub-groups. A code number composed of 8 figures for instance is large enough even for very large spare-parts stores in steel plants.

4. REHABILITATION OF THE PRODUCTION FACILITIES AND REPLACEMENT OF PARTS, ASSEMBLIES AND SUB-ASSEMBLIES

Economically spoken, the renewal of an equipment is equal to the necessary investment for the replacement or the reconditioning of equipment and plant, which has been depreciated after a certain period of operation.

A renewal policy implies the adoption of a rational and systematic investment policy, in which the maintenance policy has an important role to play.

The interdependance between the renewal, investment and maintenance policies have as a consequence thàt a maintenance policy can be agreed upon on the basis of a given renewal policy, just as a maintenance policy may determine a certain renewal policy. For example, a renewal policy which calls for rapid replacements allows a policy of relatively weak maintenance efforts, whereas a policy of full and permanent utilisation of the equipment calls for heavy maintenance efforts. In the first case, maintenance will have a more curative character, whereas in the second case it will be more preventive-oriented.

In developing countries, renewal generally are carried out according to an empiric system; renewal is decided upon when physical of economic degradation of the equipment has taken place. However, it is always underlined that industrial plant in developing countries should have a maximum lifetime. Developing countries should face the consequences of this basic option, and adapt their maintenance policies to the realisation of this option.

At this point, it should be stressed, that mathematical models exist, which allow to determine the optimum time of replacement under a given maintenance policy.

Developing countries should also adapt a national renewal policy in the short run. Their industries should take consequent action. This action will concern the maintenance activities on the one hand and the strategy when purchasing equipment on the other hand.

Possibly, renewal-, investment-, and maintenance strategies can be adopted for each industrial branch.

5. PREVENTIVE MAINTENANCE OPERATION

5.1 Preventive maintenance

The preventive maintenance file will contain all the information which is necessary for the execution of the preventive maintenance work. This information concerns the work specifications and the parts of the machine to be inspected, as well as the job planning and inspection.

The distinction is made between the following types of information:

- job instructions : the preventive maintenance card;
- planning of preventive maintenance;
- scheduling of preventive maintenance jobs;
- visit reports and the job-inspection;

Preventive maintenance job-instructions contain the detailed operations to be carried out on the machine, and the instructions which should be followed during the visit or inspection. These instructions are written on the preventive maintenance card which represents in a way a programme of maintenance. It is the most important element of preventive maintenance. The card is made by the Maintenance Planning Section. The different instructions are based on the technical documentation from the manufacturer of the machine and on experience. Certain instructions which are written on the card will require detailed information regarding work specification. In this case, it will be necessary to refer to the documentation or to prepare the job in detail. Check lists can be used to ease the visits or inspections. An inspection report is made after

each visit.

The implementation of the preventive maintenance card can take place in different ways. One method consists in making one card per machine, on which all the interventions (mechanical, electrical and control) are marked. Another and better method consists of separating the preventive work into mechanical and instrumentation work on the one hand, and electrical work on the other. For the preventive mechanical and instrumentation work, a preventive maintenance card is made per subassembly for each frequency. One will start with a card for the lowest frequency (yearly) and continue until the daily frequency. The instructions which are written down in the cards should be clear and precise and in simple language.

For the electrical preventive work a similar system is used. However, as the electrical jobs are generally less-diversified, one will start first with the description of the preventive operations of two categories.

- operations on electrical parts on machines
- operations on electrical parts in switch boxes or switch boards.

The preventive maintenance card for electrical equipment can then be prepared for each frequency in such a way that they will only mention the list of parts to be inspected, with an indication which will allow one to find the prescription in the two categories.

Based on the preventive maintenance programme per machine, a detailed plan of the work will be made for all the machines.

This plan will take into consideration the time which is necessary for executing all the jobs for each location indicated in the programme. It will also take into consideration the frequency of the monthly, quarterly and annual visits. For reasons of coordination and for practical purposes, the plan will make a distinction between the preventive mechanical maintenance and the preventive electrical maintenance and will contain at the same time the plan for lubrication activities. This lubricating job will be done at the same time.

5.2 Lubrication

The lubrication-file contains all the information which is necessary for carrying out the lubrication activities. This information may concern the work specifications and the lubricating points, as well as the planning and the inspection of the work.

A distinction should be made between the following elements:

- work instructions : the lubrication card;
- lubrication planning;
- the lubrication workload schedule.

The lubrication card contains a scheme or a photograph of the subassembly on the machine. The following informations should also appear on the card:

- the machine;
- the subassembly;
- the lubrication points;

- the type of intervention;
- the frequency;
- the lubricant which should be used.

The lubrication plan is made for those lubrication activities occuring more often than every two weeks. The lubrication plan is based on the one hand on the lubrication programme and on the other hand on the planning of preventive maintenance. Due to the fact that most of the lubrication activities with a frequency exceeding one month coincide with those of preventive maintenance, lubrication planning is included in the preventive maintenance plan.

A N N E X U R E S

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ANNEXURE 1 : Organization chart of the Maintenance Department

ANNEXURE 2 : Organization chart of the Central Maintenance Support Office

ANNEXURE 3 : Organization chart of the Mechanical and Electrical Divisions

ANNEXURE 4 : Organization chart of the Instrumentation Division

ANNEXURE 5 : Organization chart of the Central Maintenance Workshops

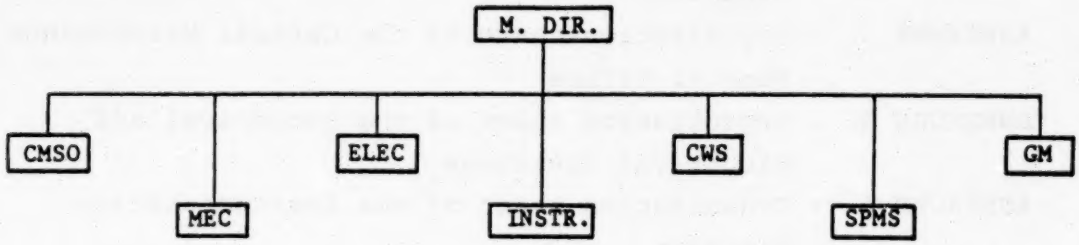
ANNEXURE 6 : Organization chart of the Spare Parts Management and Stores

ANNEXURE 7 : Organization chart of the General Maintenance Division

ANNEXURE 8 : Estimation of annual and monthly needs and consumption of spare parts

ANNEXURE 1

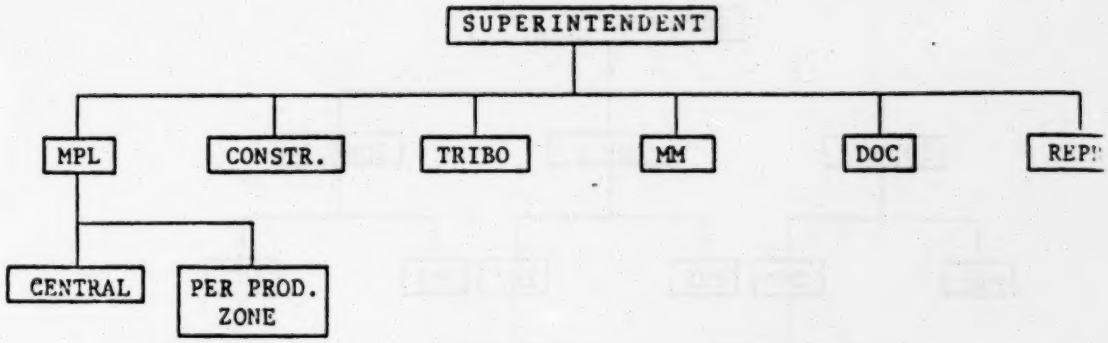
ORGANIZATION CHART OF THE MAINTENANCE DEPARTMENT



CMSO : Central maintenance support office
MEC : Mechanical division
ELEC : Electrical division
INSTR. : Instrumentation division
CWS : Central workshop
SPMS : Spare parts management and stores
GM : General maintenance division

ANNEXURE 2

CENTRAL MAINTENANCE SUPPORT OFFICE



MPL : Maintenance planning

CONSTR. : Maintenance engineering and construction

TRIBO : Tribology

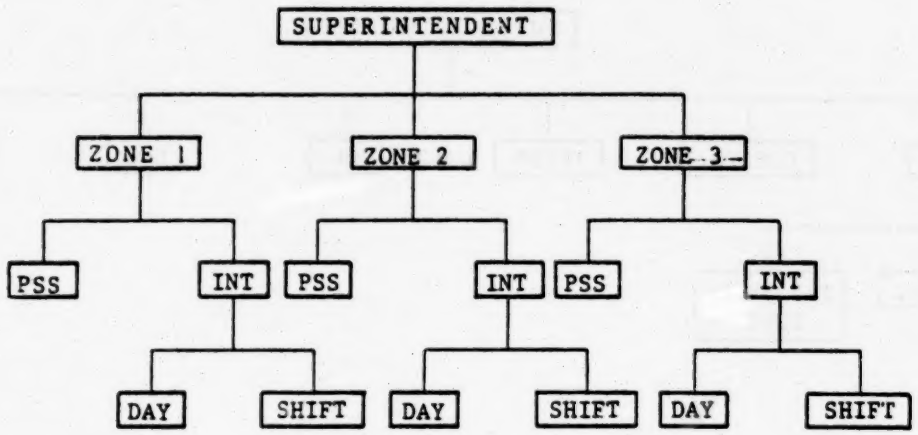
MM. : Maintenance management

DOC. : Central technical documentation

REPRO : Reprography

ANNEXURE 3

MECHANICAL AND ELECTRICAL DIVISIONS



PSS : Maintenance programming - work specifications - maintenance scheduling

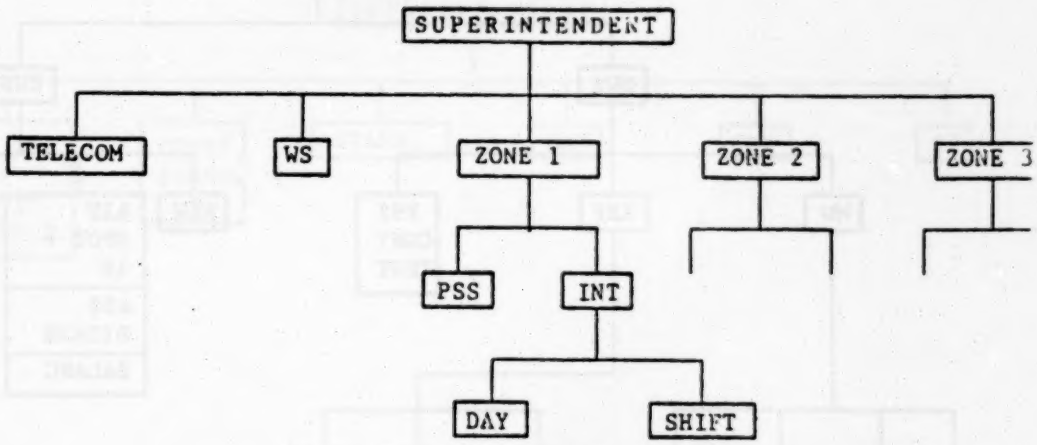
INT : Intervention

DAY : Normal hour day-team

SHIFT : 3 x 8 shift

ANNEXURE 4

INSTRUMENTATION DIVISION



TELECOM : Telecommunication section

WS : Workshop

PSS : Maintenance programming - work specification - maintenanc scheduling

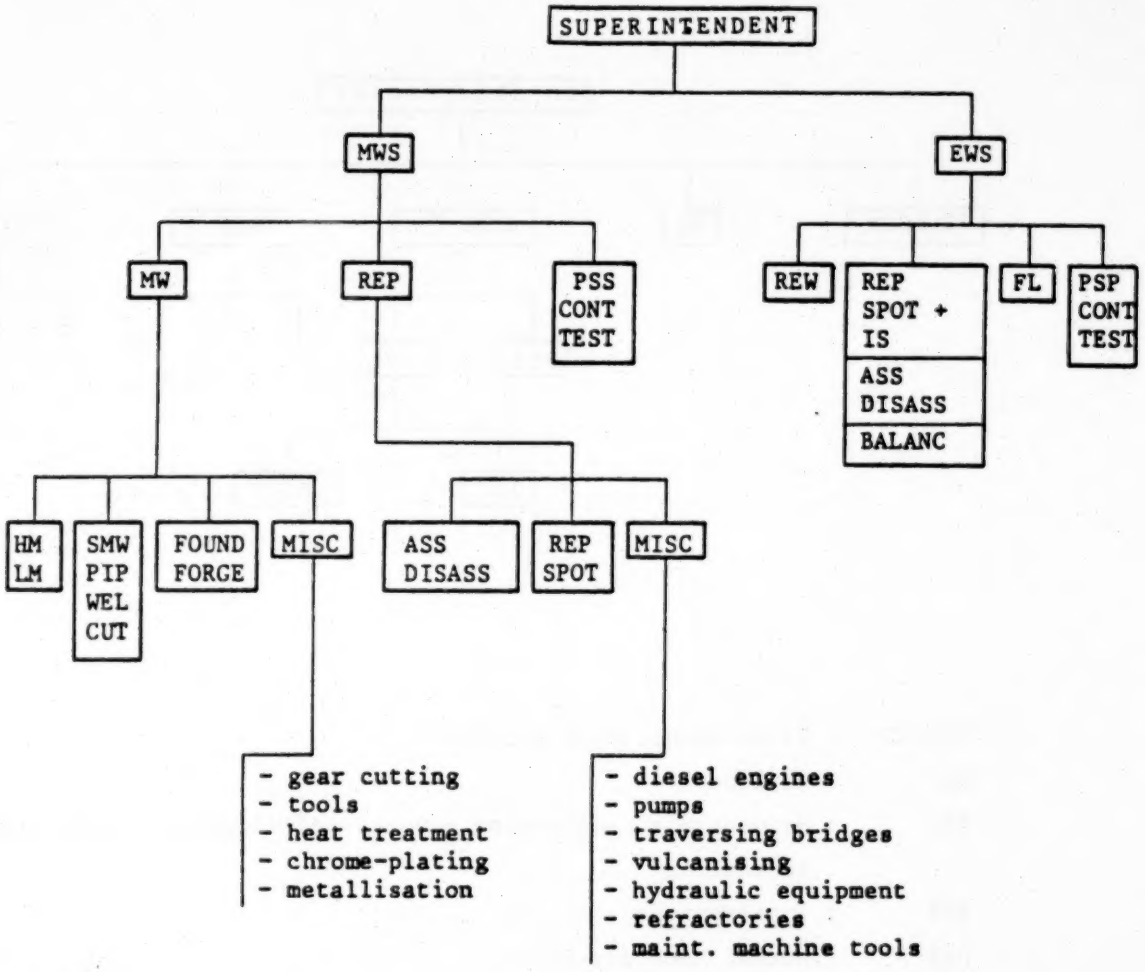
INT : Intervention

DAY : Normal hour day-team

SHIFT : 3 x 8 shift

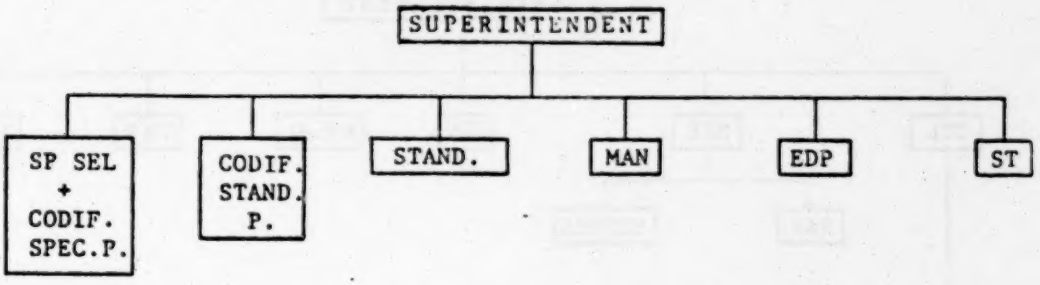
ANNEXURE 5

CENTRAL MAINTENANCE WORKSHOPS



MWS	: Mechanical workshop	CUT	: Cutting
EWS	: Electrical workshop	FOUND	: Foundry
MW	: Metal-working	MISC	: Miscellaneous
REP	: REPAIR	ASS	: Assembling
PSS	: Programming - Work specif. - scheduling	DISASS	: Disassembling
CONT	: Control	REP SPOT	: Repair on the spot
HM	: Heavy mechanics	REW	: Rewinding
LM	: Light mechanics	REP IS	: Repair in the shop
SMW	: Sheet metalworking	BALANC	: Balancing
PIP	: Piping	FL	: Factory lighting
WEL	: Welding		

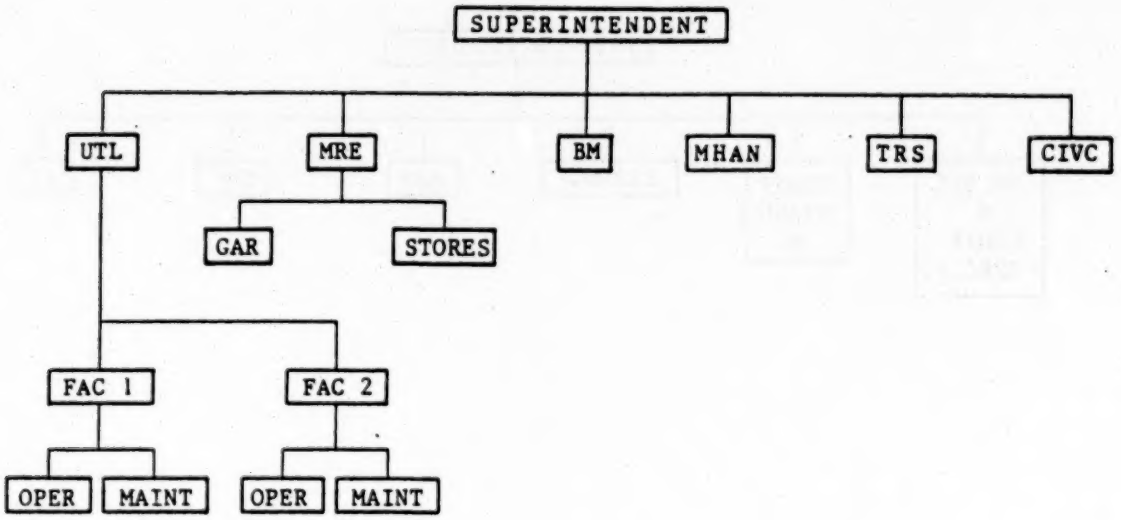
SPARE PARTS MANAGEMENT AND STORES



SP SEL : Spare parts selection
CODIF : Codification
SPEC.P. : Specific parts
STAND.P. : Standard parts
STAND : Standardization
MAN : Spare parts management
EDP : Electronic data processing
ST : Stores

ANNEXURE 7

GENERAL MAINTENANCE DIVISION



UTL : Utilities
FAC : Facility
OPER : Operation
MAINT : Maintenance
MRE : Maintenance of rolling equipment
GAR : Garage
BM : Building maintenance
MHAN : Materials handling
CIVC : Civil construction
TRS : Tracks, roads, sewerage

ANNEXURE 8

ESTIMATION OF ANNUAL AND MONTHLY NEEDS AND CONSUMPTION OF SPARE PARTS

	Estimation of spare parts needed, expressed in % of replacement value of equipment	Estimation of annual consumption of parts expressed in % of replacement value of equipment
Spare parts (safety parts included)	8 %	6 %
Standard parts	1,4 %	1 %
Current maintenance items	1,6 %	1,2 %
TOTAL	11 %	8,2 %